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A social cognitive perspective on gender disparities in self-efficacy, interest, and aspirations in science, technology, engineering, and mathematics (STEM): the influence of cultural and gender norms

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Abstract

Background: The underrepresentation of women in science, technology, engineering, and mathematics (STEM) fields is well documented in developed countries, and yet public discussion of gender disparities in STEM in China is still in its nascent stage. Endorsement of traditional gender role beliefs and conformity to social norms are pertinent to Chinese culture, which may even exacerbate the gender disparities in STEM engagement. Grounded in social cognitive career theory, the present study drew on a national sample of secondary school students ($N = 3020$) in China to estimate gender disparities in self-efficacy, interest, and aspirations in STEM and examine how cultural and gender norms influence STEM engagement.

Results: The proposed sequential mediation model was supported, in which girls were more likely to show lower levels of self-efficacy than boys; this was associated with lower interest in STEM and lower motivation to pursue STEM careers. The results also supported the moderating effect of traditional gender role beliefs and found that gender differences in self-efficacy, interest, and aspirations in STEM were more apparent among students who strongly endorsed stereotypical views of male and female roles.

Conclusions: The findings provide important implications for efforts to improve girls' access to STEM education through curriculum enrichment and out-of-school time programs to bridge the gender gap in STEM. Access to female role models and gender-responsive pedagogy is also essential to boost girls' self-efficacy in STEM and eradicate traditional gender role beliefs among all students.

Keywords: STEM, Self-efficacy, Interest, Academic and career aspirations, Traditional gender role beliefs, Conformity to social norms

Introduction

The underrepresentation of women in science, technology, engineering, and mathematics (STEM) fields is a global phenomenon (Ceci & Williams, 2011). Despite the growing number of women entering STEM education and careers, gender disparities remain deeply engrained, with women being less likely to engage in STEM education and pursue STEM careers than men (Charlesworth & Banaji, 2019; Wang & Degol, 2017). An international study across 67 countries and regions showed that the proportion of girls who were able to succeed and who had an interest in STEM studies was significantly higher than

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that of female college students who were likely to graduate from STEM fields (Stoet & Geary, 2018). Nonetheless, fewer women possessed tertiary degrees in STEM disciplines than men across the countries and regions, which indicated a potential loss of women's STEM capacity in the transition between secondary and tertiary education.

Previous studies suggested that the gender gap in STEM engagement begins in the early developmental stages and continues throughout adolescence (Charlesworth & Banaji, 2019). In the United States, it was found that in middle school, the number of boys who intend to engage in STEM-related careers is more than double the number of girls who intend to do the same (Legewie & DiPrete, 2014). These gender differences remain through high school and are even more apparent in tertiary education. This implies the continual decline of women's representation in STEM fields across consecutive stages of human development. To investigate the mechanisms underlying the gender disparities in STEM engagement, the present study drew on a national sample of secondary school students in China, which is ranked 106 among 153 countries in the Global Gender Gap Report 2020 (World Economic Forum, 2019). The low birth rate of girls and the low life expectancy of female infants in China also led to it being ranked last in health and survival. Apart from the observed gender gap in China, people are strongly influenced by traditional gender role beliefs and have a high tendency to conform to social norms. The study applied a social cognitive perspective to understand how cultural and gender norms play a role in shaping female underrepresentation in STEM.

A social cognitive perspective on gender disparities in STEM

The extant literature has focused primarily on a social cognitive perspective to account for gender disparities in STEM engagement (Wang & Degol, 2017). Previous work concerning gender disparities in STEM often rests on the untested assumption that men outperform women in mathematical and spatial abilities (reviewed by Hyde et al., 1990). Nevertheless, recent meta-analyses showed that the magnitude of gender differences in mathematics and science literacy is minimal (Else-Quest et al., 2010; Lindberg et al., 2010; Stoet & Geary, 2018) and provided further support for the gender similarities hypothesis, i.e., males and females are similar on most, but not all, psychological variables (Hyde, 2005).

Compared to the absolute cognitive ability level, relative cognitive strengths appear to be a stronger explanation for gender disparities in STEM engagement (Wang & Degol, 2017). There is converging evidence that women are more likely to perform similarly well in mathematical and verbal tasks, whereas men are more likely to have higher mathematical ability than verbal ability (Miller & Halpern, 2014; Wang et al., 2013). Thus, women may have a greater variety of career options; on the other hand, men may focus on STEM because they are relatively more competent in mathematics than language arts (Wang & Degol, 2017). Therefore, women's academic and career aspirations in STEM are likely influenced by their choices rather than their abilities (Hyde, 2016).

Gender disparities in STEM are also linked to gendered roles, values, and lifestyle preferences (Charlesworth & Banaji, 2019). Gendered perceptions of academic disciplines are developed in early childhood through socialization and education, which may impact later lifestyle and career choices (Cheryan et al., 2015). Women are socialized to have communal, group-serving, and altruistic values, whereas men are expected to have agentic, self-serving, and competitive values (Diekman et al., 2010). As STEM fields are often perceived as authoritative and competitive, they may be more congruent with men's inclinations and less compatible with the goals and values that women appear to endorse (Diekman et al., 2015). This is supported by previous studies showing that the associations between gender bias and female underrepresentation in STEM remain significant after controlling for cognitive ability and STEM performance, which highlights the potential influences of gender bias (Liu, 2018; Smyth & Nosek, 2015).

Social cognitive career theory

Social cognitive career theory (SCCT) proposes that self-efficacy (i.e., perceived capabilities to learn or perform well in a specific field) has a great influence on interest development and future educational and occupational decisions (Lent et al., 1994). Prior research examining this theory indicated that self-efficacy in a particular domain is directly related to interest and aspirations to develop in that field (Lent et al., 2018). Specifically, individuals are more likely to show interest in the domain in which they believe they are capable; this may, in turn, motivate them to pursue their education and career paths in that field (Lent et al., 1994).

Previous studies have attempted to apply social cognitive career theory to understand students' STEM engagement and development. Students' self-efficacy in STEM is associated with their interests, academic performance, and educational and occupational aspirations in STEM (Bandura et al., 2001; Lent et al., 1986; Schaefers et al., 1997). Tellhed and colleagues (2017) found that gender differences in interest in STEM majors can be explained by women's lower self-efficacy in STEM. A meta-analytic path analysis conducted by Lent et al. (2018) also provided support for the SCCT interest and choice model by showing that self-efficacy in STEM is positively associated with choice goals in STEM through heightened levels of interest in STEM. Based on the existing literature on gender differences in STEM engagement, it was hypothesized that:

> Hypothesis 1: Girls would show lower levels of self-efficacy, interest, and academic and career aspirations in STEM than boys.
> Hypothesis 2: The gender differences in academic and career aspirations in STEM would be explained by lower levels of self-efficacy and interest in STEM among girls than boys.

Traditional gender role beliefs

Gender role socialization plays an important role in undermining female representation in STEM (Kanny et al., 2014). Traditional gender role beliefs are the attitudes and expectations about appropriate roles, behaviors, and responsibilities for men and women (Eagly, 1987). Previous studies have shown that parents and teachers tend to underestimate girls' mathematical abilities even when their academic results are comparable to those of boys (Lubienski et al., 2013) and believe that boys will have better achievement in STEM fields than girls (Ceci et al., 2009). Parents' gender stereotypical beliefs are often linked to children's beliefs about their abilities (Correll, 2001). This proposition is supported by Wang and Degol (2017), who found that girls are likely to believe they lack competency in STEM fields (even though they actually outperform boys in STEM) if their parents exhibit higher levels of gender bias and that this may, in turn, reduce self-efficacy in STEM among girls. The findings corroborated the work by Inzlicht and Schmader (2012), who indicated that gender–stereotypical competence beliefs (e.g., boys are more competent and capable in STEM than girls) may have negative effects on girls' self-assessment of their STEM abilities (e.g., self-questioning, lower expectation of test performance). Using a national sample of college students in China, Yang and Gao (2019) also found that lower career expectations of parents and gender stereotypes embedded in Chinese culture negatively influence women's achievement motivation in STEM majors. Internalized gender stereotypes and their impacts on STEM self-efficacy can potentially create an ingrained belief among girls that they are incompatible with STEM, which discourages them from engaging in STEM fields.

Traditional gender stereotypes may also compel students to develop interests that fit with their gender roles (Correll, 2001; Nosek et al., 2009; Wang & Degol, 2017). Previous studies have shown that parents and teachers often recognize boys' success and abilities in STEM and neglect girls' exploration and development of interest in STEM (Lubienski et al., 2013). In addition, women are portrayed as feminine, emotional, and altruistic, and they are supposed to be more interested in arts, humanities, and social sciences, whereas men are considered masculine, rational, and competitive, and should be more interested in STEM (Diekman et al., 2010). Women who internalize such traditional gender role beliefs are likely to fit in with gender norms and have a low interest in STEM.

Traditional gender role beliefs may also influence one's career aspirations. As the goal congruity hypothesis postulates, STEM fields are perceived as incongruent with women's gender roles and goals (Diekman et al., 2010). It is because STEM work environments often exhibit a competitive and power-pursuing atmosphere, which creates a mismatch with women's gender roles. Furthermore, previous studies have documented a hostile and unsupportive climate toward female personnel in the STEM workplace (e.g., sexism, sexual harassment, and gender-based discrimination) (Charlesworth & Banaji, 2019). Women also experience less positivity, a lack of belonging, and unequal treatment in STEM work environments, which further lead to lower aspirations toward STEM-related careers (Rainey et al., 2018). It was, therefore, hypothesized that:

> Hypothesis 3: Traditional gender role beliefs would moderate the association of gender with self-efficacy, interest, and academic and career aspirations in STEM, such that the gender differences in STEM would be larger among students who endorsed higher levels of traditional gender role beliefs.

Conformity to social norms

The Chinese culture and social system are greatly influenced by collectivism and Confucianism, which expect people to conform to norms rather than show uniqueness and individuality (Bond & Smith, 1996; Chen et al., 2005; Luo et al., 2013). The social behaviors of individuals are guided by norms, obligations, and duties in collectivist cultures, instead of personal pleasure and interests (Triandis et al., 1990). Compliance with norms is fundamental for Chinese people to gain approval and acceptance in society and avoid disgracing their families (Chan & Huang, 2022; Triandis et al., 1990). Furthermore, Confucian principles heavily emphasize social norms (*Li*, 禮) and self-restraint (*Yue*, 約), maintaining that the primary developmental goal for Chinese people is to internalize and follow the social norms of their cultural community (Luo et al., 2013). It is necessary for them to treat their personal desires as subordinate, be obedient to authority (e.g., parents and elderly individuals), and consider collective interests as a whole (Luo et al., 2013). Individualistic traits and attributes such as uniqueness and autonomy are less encouraged, as these qualities may be perceived as different and deviant from social norms (Cialdini & Trost, 1998). This is evidenced by the study of Yamaguchi (1994), who found that people living in collectivist cultures had a lower need for uniqueness. Similarly, when Nevis (1983) examined Maslow's hierarchy of needs in China, the need for self-esteem was eliminated, as individuality is not valued, and the concept of "self" is defined in terms of the group. The need for self-actualization is attained by sacrificing one's preferences to achieve the group's superordinate goals (Nevis, 1983).

The emphasis on conformity to social norms in Chinese culture may contribute to gender disparities in self-efficacy, interest, and academic and career aspirations in STEM. Influenced by the traditional division of labor, women are expected to be family-centered instead of working outside the home. Compared to men, women are expected to uphold family values, leading them to sacrifice their career for their family (Williams & Ceci, 2012), and they may prefer jobs with flexible working hours (e.g., part-time jobs) so that they can take care of their families (Charlesworth & Banaji, 2019). The strong social responsibility of being the family's primary caregiver is imposed on women, which keeps them from demanding career fields (Yoshikawa et al., 2018). Individuals in Chinese societies have obligations to obey and respect familial and social expectations, so as to achieve filial piety and avoid bringing shame to their families (Luo et al., 2013; Mau, 2000). Thus, women who strongly endorse such traditional familial norms may choose not to engage in competitive and intensive careers, such as those in STEM. The impact of culture on STEM engagement was also shown in a cross-cultural study by Mau et al. (2020), who found greater gender differences in STEM self-efficacy and learning experiences among students from a collectivist culture (i.e., Taiwan) than among those from an individualist culture (i.e., the United States). It was, therefore, hypothesized that:

> Hypothesis 4: Conformity to social norms would moderate the association of gender with self-efficacy, interest, and academic and career aspirations in STEM, such that the gender differences in STEM would be larger among students who highly conformed to social norms.

The present study

Grounded in social cognitive career theory, the present study aimed to (1) estimate gender differences in self-efficacy, interest, and academic and career aspirations in STEM among secondary school students in China, (2) investigate whether self-efficacy and interest in STEM would explain gender differences in academic and career aspirations in STEM, and (3) examine the moderating effects of traditional gender role beliefs and conformity to social norms on gender differences in self-efficacy, interest, and academic and career aspirations in STEM. It was hypothesized that girls would show lower levels of efficacy, interest, and academic and career aspirations in STEM than boys (Hypothesis 1). We proposed a sequential mediation model (see Fig. 1) in which the association of gender with academic and career aspirations in STEM would be mediated by self-efficacy and interest in STEM (Hypothesis 2). In addition, we examined a moderated mediation model (see Fig. 2) in which traditional gender role beliefs (Hypothesis 3) and conformity to social norms (Hypothesis 4) would moderate the association of gender with self-efficacy, interest, and academic and career aspirations in STEM.

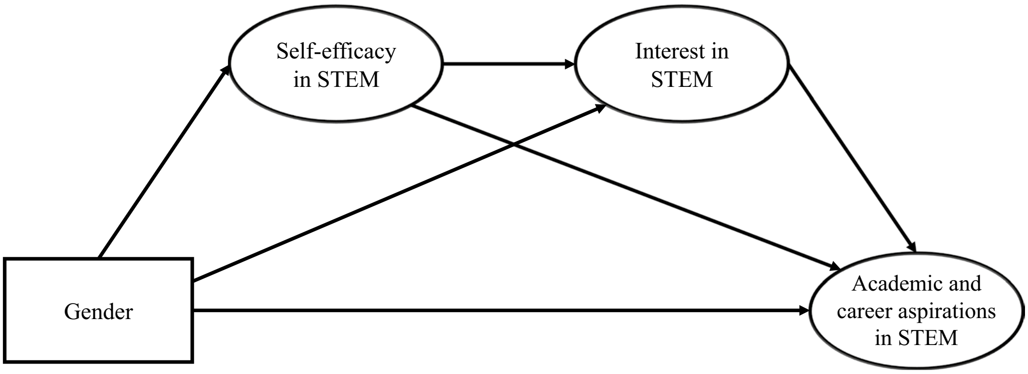

Fig. 1 Hypothesized mediation model of gender differences in self-efficacy, interest, and academic and career aspirations in STEM

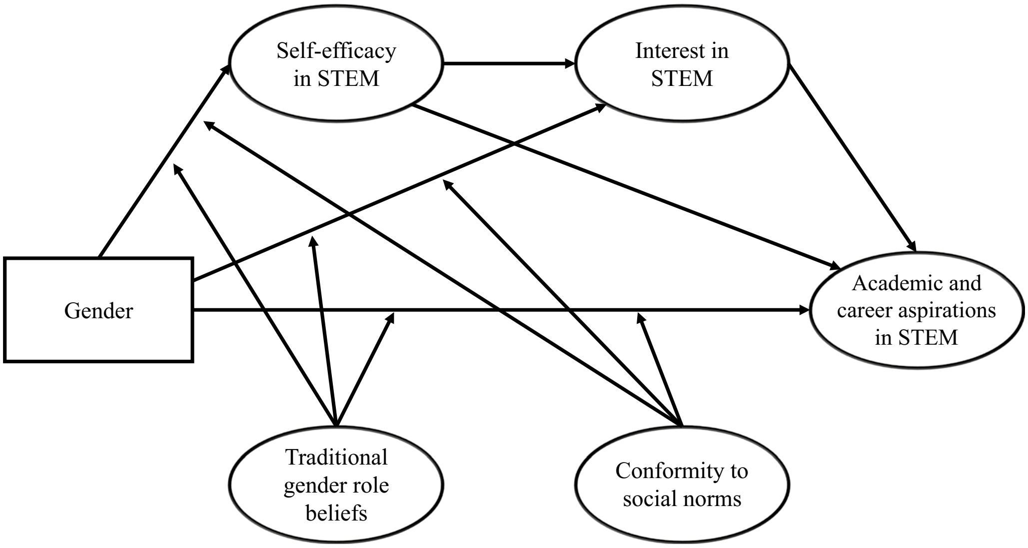

Fig. 2 Hypothesized moderated mediation model of gender differences in self-efficacy, interest, and academic and career aspirations in STEM

Methods

Participants

Study recruitment was conducted in 10 secondary schools in different geographic regions of China, including Guangdong, Zhejiang, and Shanghai. Students were provided with study information and invited to join the study. Informed consent was sought before the study began. Participants were assured of confidentiality and informed that they could withdraw from the study at any time. They were asked to complete the questionnaire on paper or online. Participants were given approximately 30 min to complete the questionnaire. The study was approved by the Human Research Ethics Committee of the corresponding author's institution.

A total of 3020 secondary school students participated in the study. Approximately 51.5% ($n = 1552$) of the participants were male, whereas 48.5% ($n = 1463$) were female. Their mean age was 15.71 years (SD = 1.54). The majority of participants were Han Chinese (97.1%, $n = 2932$), while 2.9% ($n = 87$) were ethnic minorities. Approximately 12.5% of the participants' mothers and 14.0% of the participants' fathers had attained a university or college degree. For 20.6% of the participants' mothers and 24.2% of the participants' fathers, high school was the highest level of educational attainment.

Measures

Perceptions of STEM were measured using nine self-report items adapted from Brown et al. (2016). The items assessed three dimensions: self-efficacy, interest, and academic and career aspirations in STEM. Items for self-efficacy in STEM included "I usually give up when I do not understand a STEM concept" (reverse-scored), "I am confident that I can learn STEM subjects well," and "If I work hard enough, I can learn difficult STEM concepts." Items for interest in STEM included "I enjoy learning about science, technology, engineering, and mathematics (STEM)," "I really enjoy STEM subjects (e.g., mathematics, biology, physics, chemistry, and information technology)," and "I think STEM lessons are interesting." Items for academic and career aspirations in STEM included "If I could choose in the future, I would not take any STEM courses" (reverse-scored), "If I could get into a college, I would like to study STEM," and "I would like to pursue a STEM-related career in the future." The items were rated on a 5-point scale ranging from 1 (strongly disagree) to 5 (strongly agree). Higher scores indicated higher levels of self-efficacy, interest, and academic and career aspirations in STEM. Construct validity was established using confirmatory factor analysis and the results supported a three-factor model, $\chi^2 = 882.27$ (df = 24, $p < 0.001$), CFI = 0.96, TLI = 0.94, RMSEA = 0.11, SRMR = 0.06. Modification indices were inspected to identify possible error covariances between items to improve model fit. The results suggested including an error covariance between two negatively worded items, including "I usually give up when I do not understand a STEM concept" and "If I could choose in the future, I would not take any STEM courses." After including the error covariance, the model indices improved to $\chi^2 = 265.79$ (df = 23, $p < 0.001$), CFI = 0.99, TLI = 0.98, RMSEA = 0.06, SRMR = 0.04. The internal consistency

(Cronbach's alpha) of the self-efficacy, interest, and academic and career aspirations in STEM subscales were 0.67, 0.94, and 0.78, respectively.

Traditional gender role beliefs were measured by five items from the Gender Role Attitude Scale (Lee, 2004). Items from the competence and performance subscales were used to measure beliefs and expectations concerning appropriate roles for males and females in terms of academic competence and performance. Sample items included "Males have better logical thinking, so they are more suited to mathematics and science subjects, such as physics, chemistry, and biology" and "Females have better language skills, so they are more suitable for literature and humanities subjects, such as the Chinese language, the English language, and history." The items were developed in Chinese and validated among Chinese youth populations (Lee, 2004). The items were rated on a 5-point scale ranging from 1 (strongly disagree) to 5 (strongly agree). Higher scores represented a stronger endorsement of traditional gender role beliefs. The scale showed convergent validity with measures of attitudes toward feminine men and attitudes toward homosexuality (Huang & Lin, 2011). Construct validity was examined using confirmatory factor analysis: $\chi^2 = 816.91$ (df $= 5$, $p < 0.001$), CFI $= 0.90$, TLI $= 0.81$, RMSEA $= 0.23$, SRMR $= 0.06$. An inspection of the modification indices suggested including an error covariance between the two items, i.e., "Males have better logical thinking, so they are more suited to mathematics and science subjects, such as physics, chemistry, and biology" and "Females have better language skills, so they are more suitable for literature and humanities subjects, such as the Chinese language, the English language, and history." The two items are both related to gender stereotypes concerning subject choice. After including the error covariance, the model indices improved to $\chi^2 = 64.16$ (df $= 4$, $p < 0.001$), CFI $= 0.99$, TLI $= 0.98$, RMSEA $= 0.07$, SRMR $= 0.02$. The internal consistency (Cronbach's alpha) of the scale was 0.87 in the present study.

Conformity to social norms was measured by five items from the conformity to norms subscale of the Asian Values Scale (Kim et al., 1999). The sample items included "One should not deviate from familial and social norms" and "One need not conform to one's family's and the society's expectations" (reverse scored). The participants were asked to respond to the items on a 4-point scale ranging from 1 (strongly disagree) to 4 (strongly agree). Higher scores indicated stronger adherence to familial and social expectations, norms, and practices. The scale showed good concurrent and discriminant validity with measures of acculturation (Kim et al., 1999). Construct validity was examined using confirmatory factor analysis: $\chi^2 = 473.42$ (df $= 5$, $p < 0.001$), CFI $= 0.91$, TLI $= 0.81$, RMSEA $= 0.18$, SRMR $= 0.07$. An inspection of the modification indices suggested including an error covariance between the two items, including "One need not follow one's family's and the society's norms" and "One need not conform to one's family's and the society's expectations." The two items are related to conformity to norms and expectations of the family and society. After including the error covariance, the model indices improved to $\chi^2 = 48.78$ (df $= 4$, $p < 0.001$), CFI $= 0.99$, TLI $= 0.98$, RMSEA $= 0.06$, SRMR $= 0.03$. The internal consistency (Cronbach's alpha) of the scale was 0.72.

Data analysis

Descriptive statistics were used to examine self-efficacy, interest, and academic and career aspirations in STEM. All study variables were screened for univariate normality (i.e., skewness ≤ 3.0 and kurtosis ≤ 10.0) (Weston & Gore, 2006) before the main analysis was conducted. The skewness and kurtosis for the main study variables were within the acceptable ranges. Independent-sample *t* tests were conducted to determine gender differences in self-efficacy, interest, and academic and career aspirations in STEM. Cohen's *d* was calculated to estimate the effect sizes and evaluate the magnitude of group differences. Cohen's *d* values of 0.20, 0.50, and 0.80 were considered small, medium, and large effect sizes, respectively (Cohen, 1992). Pearson correlation coefficients were calculated to examine the relationships between the study variables.

Structural equation modeling (SEM) was conducted to examine the mediation model of gender differences in STEM (Model 1). Gender was coded as a dichotomous variable, with females as the reference category. A measurement model was first estimated by loading items onto their respective latent constructs using confirmatory factor analysis. After confirming the fit of the measurement model, we estimated a structural model to test the hypothesized relationships between gender, self-efficacy in STEM, interest in STEM, and academic and career aspirations in STEM, controlling for demographic variables (i.e., age, ethnicity, mother's education level, and father's education level). Mplus version 7.1 was used to test the measurement and structural models using full maximum likelihood estimation. The goodness-of-fit of the models was evaluated using the χ^2 statistic and four other fit indices: the comparative fit index (CFI), Tucker–Lewis index (TLI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR) (Hu & Bentler, 1999). CFI and TLI values of 0.95 or above, RMSEA values of 0.06 or below, and SRMR values of 0.08 or below indicate a good fit between the model and the observed data (Hu & Bentler, 1999). The indirect effects of gender on academic and career aspirations in STEM were examined using 1000 bias-corrected bootstrapped samples with 95% confidence intervals (CI).

A latent moderated structural equation modeling approach (LMS) was used to examine the hypothesized moderated mediation model, as depicted in Fig. 2. A three-step estimation procedure recommended by Maslowsky and colleagues (2015) was adopted. We first examined a measurement model to evaluate the fit of the observed variables to the latent variables. Second, a structural model without the latent interaction terms was estimated to examine the structural relationships between the latent constructs, controlling for demographic variables. Third, we examined a latent moderated structural equation model by including the latent interaction terms, i.e., gender × traditional gender role beliefs (Model 2) and gender × conformity to social norms (Model 3). All variables were standardized prior to model estimation. When the latent interaction terms were significant, we examined the direct and indirect effects of gender on the STEM variables at low (1 SD below the mean), medium (at the mean), and high (1 SD above the mean) levels of moderator variables.

Results

Gender differences in self-efficacy, interest, and aspirations in STEM

The independent-sample t test showed significant gender differences in self-efficacy in STEM ($t = 13.57$, $p < 0.001$, $d = 0.49$), interest in STEM ($t = 18.60$, $p < 0.001$, $d = 0.68$), and academic and career aspirations in STEM ($t = 19.27$, $p < 0.001$, $d = 0.70$). Girls reported significantly lower levels of self-efficacy, interest, and academic and career aspirations in STEM than boys. The results provide support for Hypothesis 1. Table 1 shows the number and percentage of respondents in agreement (agree or strongly agree) with the statements on self-efficacy, interest, and aspirations in STEM by gender. Around 60.2% of boys indicated that they were confident that they could learn STEM subjects well (self-efficacy in STEM), while only 37.5% of girls did so. The results also showed that 55.2% of boys enjoyed learning about STEM (interest in STEM), whereas only 25.8% of girls enjoyed learning about STEM. In addition, 49.5% of boys wanted to pursue STEM-related careers in the future (academic and career aspirations in STEM), while only 19.8% of girls did the same.

Pearson correlation coefficients were calculated to examine the relationships between the STEM variables. Self-efficacy in STEM was positively related to interest in STEM ($r = 0.67$, $p < 0.001$) and academic and career aspirations in STEM ($r = 0.63$, $p < 0.001$). Interest in STEM was positively related to academic and career aspirations in STEM ($r = 0.75$, $p < 0.001$). Table 2 shows descriptive statistics and correlations of the study variables.

A mediation model of gender differences in STEM

The measurement model showed a good fit to the data, $\chi^2 = 306.57$ ($df = 29$, $p < 0.001$), CFI = 0.99, TLI = 0.98, RMSEA = 0.06, SRMR = 0.03. All loadings of the items on their latent constructs were statistically significant (ps < 0.001). The structural model also showed a good model fit, $\chi^2 = 352.79$ ($df = 53$, $p < 0.001$), CFI = 0.99, TLI = 0.98, RMSEA = 0.04, SRMR = 0.03. The results

Table 1 Gender differences in self-efficacy, interest, and academic and career aspirations in STEM

	Entire sample (*N* = 3020)	**Boys (*n* = 1552)**	**Girls (*n* = 1463)**
	***n* (%)**	***n* (%)**	***n* (%)**
Self-efficacy in STEM			
I usually give up when I do not understand a STEM concept*	600 (19.9%)	281 (18.1%)	319 (21.8%)
I am confident that I can learn STEM subjects well	1485 (49.2%)	934 (60.2%)	549 (37.5%)
If I work hard enough, I can learn difficult STEM concepts	1919 (63.5%)	1069 (68.9%)	848 (58.0%)
Interest in STEM			
I enjoy learning about science, technology, engineering, and mathematics (STEM)	1238 (41.0%)	857 (55.2%)	378 (25.8%)
I really enjoy STEM subjects (e.g., mathematics, biology, physics, chemistry, and information technology)	1279 (42.4%)	881 (56.8%)	396 (27.1%)
I think STEM lessons are interesting	1381 (45.7%)	893 (57.5%)	486 (33.2%)
Academic and career aspirations in STEM			
If I could choose in the future, I would not take any STEM courses*	639 (21.2%)	281 (18.1%)	358 (24.5%)
If I could get into a college, I would like to study STEM	1132 (37.5%)	812 (52.3%)	318 (21.7%)
I would like to pursue a STEM-related career in the future	1061 (35.1%)	769 (49.5%)	290 (19.8%)

*Items are reverse coded

Table 2 Descriptive statistics and correlations of study variables

	1	2	3	4	5
1. Self-efficacy in STEM	–				
2. Interest in STEM	0.67***	–			
3. Academic and career aspirations in STEM	0.63***	0.75***	–		
4. Traditional gender role beliefs	0.11***	0.14***	0.13***	–	
5. Conformity to social norms	0.14***	0.03	0.06**	0.06**	–
Cronbach's α	0.67	0.94	0.78	0.87	0.72
Range	1–5	1–5	1–5	1–5	1–4
Mean	3.56	3.45	3.28	3.08	2.99
SD	0.81	1.10	0.97	0.82	0.55

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

showed that gender was significantly associated with self-efficacy in STEM ($B = 0.20$, $p < 0.001$), interest in STEM ($B = 0.23$, $p < 0.001$), and academic and career aspirations in STEM ($B = 0.12$, $p < 0.001$). Boys were more likely to have higher levels of self-efficacy, interest, and academic and career aspirations in STEM than girls. Self-efficacy in STEM was positively associated with interest in STEM ($B = 2.28$, $p < 0.001$) and academic and career aspirations in STEM ($B = 0.23$, $p < 0.001$). Interest in STEM was positively associated with academic and career aspirations in STEM ($B = 0.31$, $p < 0.001$). The model explained 65.5% of the variance in academic and career aspirations in STEM. Table 3 shows the unstandardized path coefficients of the hypothesized mediation model.

Bootstrapping analysis was conducted to examine the indirect effects of gender on academic and career aspirations in STEM. Gender had significant effects on academic and career aspirations in STEM via self-efficacy in STEM ($B = 0.05$, 95% CI = 0.03, 0.07) and interest in STEM ($B = 0.07$, 95% CI = 0.05, 0.09). In addition, the indirect effect of gender on academic and career aspirations in STEM was sequentially mediated by self-efficacy and interest in STEM ($B = 0.14$, 95% CI = 0.11, 0.17). The findings lend support to Hypothesis 2.

Moderating effects of traditional gender role beliefs

The results indicated that the measurement model had a good fit to the data, $\chi^2 = 726.74$ (df = 79, $p < 0.001$), CFI = 0.98, TLI = 0.97, RMSEA = 0.05, SRMR = 0.04. All loadings of the items on their latent constructs were statistically significant (ps < 0.001). After confirming the measurement model, we specified a structural model without the latent interaction terms. The structural model yielded a good model fit, $\chi^2 = 957.48$ (df = 124, $p < 0.001$), CFI = 0.97, TLI = 0.97, RMSEA = 0.05, SRMR = 0.05. Finally, we used the LMS method to test the hypothesized relationships between the variables (see Fig. 2). Table 3 summarizes the results of unstandardized path coefficients of the hypothesized moderated mediation model (see Model 2). There were significant gender differences in self-efficacy in STEM ($B = 0.17$, $p < 0.001$), interest in STEM ($B = 0.20$, $p < 0.001$), and academic and career aspirations in STEM ($B = 0.10$, $p < 0.001$). The interaction effects between gender and traditional gender role beliefs were significantly associated with self-efficacy in STEM ($B = 0.12$, $p < 0.001$), interest in STEM ($B = 0.10$, $p < 0.001$), and academic and career aspirations in STEM ($B = 0.03$, $p = 0.049$).

To interpret the interaction effect, we examined gender differences in self-efficacy, interest, and aspirations in STEM at low, medium, and high levels of traditional gender role beliefs (see Table 4). Consistent with Hypothesis 3, the results indicated that the effect of gender on self-efficacy in STEM was stronger among students with higher levels of traditional gender role beliefs ($B = 0.29$, 95% CI = 0.23, 0.34) than among those with lower levels of traditional gender role beliefs ($B = 0.06$, 95% CI = 0.01, 0.10). Compared to those with lower levels of traditional gender role beliefs ($B = 0.10$, 95% CI = 0.01, 0.18), students with higher levels of traditional gender role beliefs ($B = 0.30$, 95% CI = 0.21, 0.39) were more likely to show a gender difference in interest in STEM. In addition, the effect of gender on academic and career aspirations in STEM was stronger among students with higher levels of traditional gender role beliefs ($B = 0.13$, 95% CI = 0.09, 0.17) than among those with lower levels of traditional gender role beliefs ($B = 0.07$, 95% CI = 0.03, 0.10).

We also examined whether traditional gender role beliefs would moderate the indirect effects of gender on academic and career aspirations in STEM. The results showed that the indirect association between gender and aspiration in STEM via self-efficacy in STEM was stronger among students with higher levels of traditional gender role beliefs ($B = 0.06$, 95% CI = 0.04, 0.08) than among those with lower levels of traditional gender role beliefs ($B = 0.01$, 95% CI = 0.002, 0.02). Similarly, the

Table 3 Unstandardized and standardized path coefficients of mediation model and moderated mediation model

Parameter estimates	**Mediation (Model 1)**		**Moderated mediation (Model 2)**		**Moderated mediation (Model 3)**	
	B (SE)	***β***	**B (SE)**	***β***	**B (SE)**	***β***
Measurement model						
Self-efficacy in STEM → Item 1	1.00	0.31***	1.00	0.31***	1.00	0.35***
Self-efficacy in STEM → Item 2	2.85 (0.17)***	0.89***	2.85 (0.17)***	0.89***	2.44 (0.13)***	0.88***
Self-efficacy in STEM → Item 3	2.15 (0.13)***	0.75***	2.16 (0.13)***	0.75***	1.86 (0.10)***	0.75***
Interest in STEM → Item 1	1.00	0.90***	1.00	0.90***	1.00	0.90***
Interest in STEM → Item 2	1.06 (0.01)***	0.94***	1.06 (0.01)***	0.94***	1.06 (0.01)***	0.94***
Interest in STEM → Item 3	1.03 (0.01)***	0.91***	1.03 (0.01)***	0.91***	1.03 (0.01)***	0.91***
Academic and career aspirations in STEM → Item 1	1.00	0.41***	1.00	0.41***	1.00	0.42***
Academic and career aspirations in STEM → Item 2	2.22 (0.09)***	0.96***	2.22 (0.09)***	0.96***	2.16 (0.09)***	0.96***
Academic and career aspirations in STEM → Item 3	2.14 (0.09)***	0.94***	2.14 (0.09)***	0.94***	2.09 (0.09)***	0.94***
Traditional gender role beliefs → Item 1	–	–	1.00	0.71***	–	–
Traditional gender role beliefs → Item 2	–	–	1.04 (0.02)***	0.75***	–	–
Traditional gender role beliefs → Item 3	–	–	1.11 (0.03)***	0.79***	–	–
Traditional gender role beliefs → Item 4	–	–	1.26 (0.03)***	0.86***	–	–
Traditional gender role beliefs → Item 5	–	–	0.91 (0.03)***	0.59***	–	–
Conformity to social norms → Item 1	–	–	–	–	1.00	0.56***
Conformity to social norms → Item 2	–	–	–	–	0.24 (0.03)***	0.17***
Conformity to social norms → Item 3	–	–	–	–	0.86 (0.02)***	0.49***
Conformity to social norms → Item 4	–	–	–	–	1.44 (0.08)***	0.80***
Conformity to social norms → Item 5	–	–	–	–	0.97 (0.05)***	0.57***
Structural model						
Gender → Self-efficacy in STEM	0.20 (0.02)***	0.57***	0.17 (0.02)***	0.55***	0.21 (0.02)***	0.57***
Gender → Interest in STEM	0.23 (0.03)***	0.22***	0.20 (0.03)***	0.22***	0.20 (0.03)***	0.22***
Self-efficacy in STEM → Interest in STEM	2.28 (0.18)***	0.77***	2.16 (0.13)***	0.77***	1.89 (0.10)***	0.78***
Gender → Academic and career aspirations in STEM	0.12 (0.01)***	0.24***	0.10 (0.01)***	0.24***	0.10 (0.01)***	0.24***
Self-efficacy in STEM → Academic and career aspirations in STEM	0.23 (0.05)***	0.16***	0.20 (0.04)***	0.16***	0.18 (0.03)***	0.16***
Interest in STEM → Academic and career aspirations in STEM	0.31 (0.02)***	0.63***	0.29 (0.02)***	0.63***	0.30 (0.02)***	0.63***
Traditional gender role beliefs → Self-efficacy in STEM	–	–	-0.03 (0.01)*	-0.07*	–	–
Gender × Traditional gender role beliefs → Self-efficacy in STEM	–	–	0.12 (0.02)***	0.13***	–	–
Traditional gender role beliefs → Interest in STEM	–	–	-0.03 (0.03)	-0.03	–	–
Gender × Traditional gender role beliefs → Interest in STEM	–	–	0.10 (0.04)**	0.04**	–	–
Traditional gender role beliefs → Academic and career aspirations in STEM	–	–	-0.01 (0.01)	-0.02	–	–
Gender × Traditional gender role beliefs → Academic and career aspirations in STEM	–	–	0.03 (0.02)*	0.03*	–	–
Conformity to social norms → Self-efficacy in STEM	–	–	–	–	0.12 (0.07)	0.06
Gender × Conformity to social norms → Self-efficacy in STEM	–	–	–	–	0.04 (0.09)	0.01
Conformity to social norms → Interest in STEM	–	–	–	–	-0.05 (0.12)	-0.01
Gender × Conformity to social norms → Interest in STEM	–	–	–	–	-0.20 (0.15)	-0.02
Conformity to social norms → Academic and career aspirations in STEM	–	–	–	–	-0.05 (0.05)	-0.02
Gender × Conformity to social norms → Academic and career aspirations in STEM	–	–	–	–	-0.09 (0.07)	-0.02

Gender was coded as a dichotomous variable with female as the reference category; *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

indirect effect of gender on aspiration in STEM via interest in STEM was stronger among students with higher levels of traditional gender role beliefs ($B = 0.09$, 95% CI = 0.06, 0.12) than among those with lower levels of traditional gender role beliefs ($B = 0.03$, 95% CI = 0.003, 0.05). Moreover, the results revealed that the indirect association between gender and aspiration in STEM via self-efficacy and interest in STEM was stronger

Table 4 Conditional effects of gender at low, medium, and high levels of traditional gender role beliefs

Parameter estimates	Low levels of traditional gender role beliefs		Medium levels of traditional gender role beliefs		High levels of traditional gender role beliefs	
	B	95% CI	B	95% CI	B	95% CI
Direct effects						
Gender → Self-efficacy in STEM	0.06*	0.01, 0.10	0.17***	0.14, 0.21	0.29***	0.23, 0.34
Gender → Interest in STEM	0.10*	0.01, 0.18	0.20***	0.15, 0.25	0.30***	0.21, 0.39
Gender → Academic and career aspirations in STEM	0.07**	0.03, 0.10	0.10***	0.08, 0.12	0.13***	0.09, 0.17
Indirect effects						
Gender → Self-efficacy in STEM → Academic and career aspirations in STEM	0.01*	0.002, 0.02	0.04***	0.02, 0.05	0.06***	0.04, 0.08
Gender → Interest in STEM → Academic and career aspirations in STEM	0.03*	0.003, 0.05	0.06***	0.04, 0.07	0.09***	0.06, 0.12
Gender → Self-efficacy in STEM → Interest in STEM → Academic and career aspirations in STEM	0.04*	0.01, 0.07	0.11***	0.09, 0.13	0.18***	0.15, 0.22

Gender was coded as a dichotomous variable with female as the reference category; $^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$

among students with higher levels of traditional gender role beliefs ($B=0.18$, 95% CI = 0.15, 0.22) than among those with lower levels of traditional gender role beliefs ($B=0.04$, 95% CI = 0.01, 0.07).

Moderating effects of conformity to social norms

The results indicated that the measurement model had an acceptable fit to the data, $\chi^2=1320.20$ (df = 80, $p<0.001$), CFI = 0.95, TLI = 0.94, RMSEA = 0.07, SRMR = 0.06. All loadings of the items on their latent constructs were statistically significant (ps < 0.001). After confirmation of the measurement model, a structural model without the latent interaction terms was estimated and the results showed an acceptable model fit, $\chi^2=1389.28$ ($df=125$, $p<0.001$), CFI = 0.95, TLI = 0.94, RMSEA = 0.06, SRMR = 0.05. Finally, the LMS method was used to examine the moderating effects of conformity to social norms (Model 3). As shown in Table 3, the interaction effects between gender and conformity to social norms were not significantly associated with self-efficacy in STEM ($B=0.04$, $p=0.64$), interest in STEM ($B=-0.20$, $p=0.18$), and academic and career aspirations in STEM ($B=-0.09$, $p=0.16$). The findings do not provide support for Hypothesis 4.

Discussion

The present study is one of the first few published studies to examine gender differences in self-efficacy, interest, and aspirations in STEM in China. Very limited research has examined gender disparities in STEM in China, where the public discussion of gender disparities in STEM is in its nascent stage (Liu, 2018; Yang & Gao, 2019). Consistent with the hypothesis, the results indicated that girls showed significantly lower levels of self-efficacy in STEM than boys, and the difference was of medium magnitude. In other words, girls in China were less likely to believe that they had the ability to perform well in STEM than boys, resulting in self-doubt and lower performance expectations. In addition, there were significant gender differences in interest and aspirations in STEM, and the differences were of medium-to-large magnitude. Girls were less likely to develop an interest in STEM and were less motivated to pursue STEM-related professions in their future education and career endeavors than boys. The findings were consistent with those from previous studies conducted in Western societies (Else-Quest et al., 2010; Legewie & DiPrete, 2014; Lindberg et al., 2010), showing female underrepresentation in STEM. It is important to consider our findings within the context of the literature documenting substantial gender disparities experienced by students in China.

The results provided empirical support for the hypothesized sequential mediation model of gender differences in STEM engagement. In line with the proposition of social cognitive career theory (Lent et al., 1994), the results showed that self-efficacy in STEM was positively associated with interest in STEM, which, in turn, was related to higher levels of academic and career aspirations in STEM among Chinese students. The findings were in accordance with the proposition of the SCCT interest and choice model (Lent et al., 2018), in which stronger self-efficacy beliefs may foster greater interest in STEM pursuits and predict educational and occupation choice goals in STEM-related fields. Most importantly, the present study integrated a gender perspective into the theory by showing that girls were less likely to form an enduring interest in STEM than boys, as girls view themselves as less competent in performing well in mathematical, scientific, and technical tasks. This, in turn, might make them less likely to develop academic aspirations and pursue career paths in STEM-related fields (Bandura et al., 2001).

Traditional gender role beliefs moderated the associations of gender with self-efficacy, interest, and aspirations in STEM, in which gender differences in STEM were more apparent among those who strongly endorsed stereotypical views of male and female roles (Inzlicht & Schmader, 2012; Nosek et al., 2009). Girls who had higher levels of traditional gender role beliefs were likely to doubt their STEM abilities and have a lower self-efficacy in STEM. Girls who lose confidence in their abilities to solve STEM problems and perform STEM tasks might then show lower interest in STEM and be less motivated to consider and pursue STEM-related careers than boys. On the other hand, boys who endorsed higher levels of traditional gender role beliefs were more inclined to believe that they perform well in STEM, which, in turn, boosts their determination in STEM-related careers. The findings imply that traditional gender role beliefs play a significant role in reinforcing and strengthening female underrepresentation in STEM engagement (Charlesworth & Banaji, 2019). In particular, gender role attitudes exacerbate the gender difference in self-efficacy in STEM, which serves to maintain girls' lower interest and career aspirations as compared to boys in STEM fields.

Furthermore, the results showed that conformity to familial and social norms did not contribute to gender differences in STEM among Chinese students. Contrary to the hypothesis, the moderating effect of conformity to social norms on the associations of gender with self-efficacy, interest, and academic and career aspirations in STEM was not significant. Students who strongly endorsed social norms did not necessarily conform to the gender division in STEM engagement. Nevertheless, the results found that conformity to social norms was positively correlated with self-efficacy and aspirations in STEM. One possible explanation is the commonly held belief that STEM is a pathway to success and achievement in Chinese societies. As STEM careers are generally considered well paid and secure, both boys and girls who conform to social norms prefer to select STEM careers to achieve financial success and upward social mobility. This phenomenon is known as the "educational-gender-equality paradox," which may explain why developing countries have smaller gender gaps in STEM fields (Stoet & Geary, 2018).

Practical implications

The findings from this first-known study of how gender and cultural norms influence gender disparities in STEM in China provide evidence supporting the need for STEM education for girls. As the present study shows, low self-efficacy is likely to cause girls to lose interest in STEM. It is imperative to facilitate the development of spatial abilities, critical thinking skills, and problem-solving skills in primary education, because these skills are essential to boosting girls' self-confidence and abilities in STEM later in their educational and career trajectories. This can be done by introducing a thorough revamp of the school curriculum and offering out-of-school time programs (e.g., after-school supplementary classes, summer schools, and enrichment programs) to bridge the STEM achievement gender gap (Young et al., 2016). Teachers should also build a positive and safe STEM learning environment, where girls feel valued and are encouraged to seek support when they perceive that they are unable to accomplish a STEM-related task or that they are not as competent as boys in STEM classes (George, 2019). In addition, providing access to female STEM role models (e.g., female scientists, engineers, and STEM college students) through mentorship programs may be instrumental to inspiring girls by ensuring that they see a future for themselves in STEM fields and improving their self-efficacy and career aspirations in STEM (Drury et al., 2011).

Apart from fostering self-efficacy in STEM, it is also important to cultivate a gender-bias-free environment to eliminate gender disparities in STEM engagement. Gender-responsive pedagogy is the key to allowing all learners to actively participate in the classroom regardless of their gender (Aikman et al., 2005). First, traditional gender role beliefs should be explicitly addressed and included in the curriculum to debunk gender stereotypes and misconceptions among students. Teaching and learning materials may serve to reproduce systems of gender inequity; thus, teachers should review and ensure that their instructional materials show women and men taking on a wide variety of roles and responsibilities (e.g., both women and men are represented as scientists, engineers, and programmers) (Forum for African Women Educationalists, 2018). Moreover, teachers must identify and be aware of their gender biases in classroom interactions (e.g., praising boys more than girls for their performance on STEM tasks, not expecting girls to do well in mathematics and science, and assigning boys to be the leaders in STEM-related group work) (Sadker & Zittleman, 2007). Teachers should also ensure that gender-responsive language is used in the classroom and sensitize students to the gender stereotypical messages they receive in their daily lives.

Limitations

Although the present study provides valuable insight into gender disparities in STEM engagement in China, a few limitations must be acknowledged. First, the cross-sectional nature of the study does not allow for the testing of the directionality of the relationships among the study variables. Future research should examine the proposed hypotheses using a longitudinal research design. Second, the study results were based solely on self-report data and, thus, might be subject to common method bias. Future work should include objective data (e.g., STEM achievement test scores) in conjunction with subjective self-report questionnaires to improve the measurement of STEM engagement. Third, the study relied on nonprobability sampling, which may hinder the generalizability of the findings. The validity of the findings can be strengthened using a nationally representative sample in future research. Data on gender disparities in STEM engagement should be systematically collected in the China Education Panel Survey, which can inform national policies on STEM education.

Conclusions

Overall, the present study adds to growing evidence of gender disparities in self-efficacy, interest, and academic and career aspirations in STEM in China (Liu, 2018; Yang & Gao, 2019). The results showed that girls were less likely to perceive that they have the capabilities to do well in mathematical, scientific, and technical tasks than boys, which might make girls lose interest in STEM and subsequently lack motivation to pursue STEM as academic and career endeavors. The gender difference in STEM engagement was even more prominent among students who endorsed higher levels of traditional gender role beliefs. Efforts to improve girls' access to STEM education through curriculum enrichment and out-of-school time programs are necessary to bridge the gender gap in STEM. Access to female role models and gender-responsive pedagogy is also needed to boost girls' self-efficacy in STEM and eradicate traditional gender role beliefs among all students.

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Author contributions
RCHC was responsible for study conceptualization and design, data analysis, and the writing of the manuscript. The author read and approved the final manuscript.

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Availability of data and materials
The datasets generated and/or analyzed during the current study are not publicly available due to concerns regarding confidentiality and data protection.

Declarations

Competing interests
The author has no conflicts of interest related to this study.

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